

7. 1696

The Making of
ROCKETS.

In Two Parts.

The First
Containing the Making of Rockets
for the meanest Capacity.

The other
To make Rockets by a Duplicate
Proposition, to 1000 pound
Weight or higher.

*Experimentally and Mathematically
Demonstrated, By*
ROBERT ANDERSON.

L O N D O N :

Printed for Robert Morden, at the Atlas in
Cornhil. 1696.

11

ROCKETS



To make by a Duplicate
1840 to 1850
W. 2

Experiments on the
Robert Anderson

LONDON

Printed for Robert Anderson at the
Great Court

To the Right Honourable

H E N R Y

Earl of Romney.

*Vicount Sidney of Sheppy, Baron
of Milton, Master General of his
Majesty's Ordnance, Constable of
Dover Castle, Lord Warden of the
Cinque Ports, and one of the Lords
of his Majesty's most Honourable
Privy Council.*

WELL knowing my
most Noble Lord,
that these things will easily receive
Perfection in your Hands, which
for many Reasons are beyond my
reach.

This Treatise (if it may de-
serve that name) is the least in

A z

Bulk,

Epistle Dedicatory.

Bulk, and seemingly relating to the sleightest Subject I have met withal in *Pyrotechnia*. But in the many Volumns great and small that I have read relating to these Matters in our own and other Languages; I do not find the least Pretence or Thought of doing that which here is undertaken, *viz.* To raise so great a heap of Fire, and to confirm the Fact by the greatest Proofs that can be had or wish'd for, which are Experiments and Demonstrations Mathematical. Yet this alone is not the matter aim'd at, the Problem is universal, and applicable to the Fortifications of all sorts of Guns and other Engines with their Carriages, &c. and is to increase or decrease the strength of Materials according to the Effects and Services required. But the greatest Skill in this Undertaking being

to

Epistle Dedicatory.

to adjust the Instrument and Means in a due and proper Proportion to the Effect sought for; I do with all Humility and profound Respect make offer of this small Essay.

It is your Lordships great Abilities and Merit, that has enabled you to tread the intricate and painful steps of Greatness; and by the well discharging so many Eminent Employments, to add, (if any thing can be added) to the Great Name of your Renowned Ancestors. An ardent Zeal for the Welfare and Honour of your Country, has always been the inbred Vertue of your Family, and which is brought to its Perfection in your self.

The Name of *Master General* of the *Ordnance*, lays Claim to all my (more than 25 Years) Experience

Epistle Dedicatory,

perience and Studies about the Art of Shooting in all sorts of Great Artillery amounts to: But the adding something (according to my poor Sphere and Capacity) to the Defence, Safety and Reputation of my Native Country, has at all times so intirely govern'd me, that upon this account also, and indeed chiefly, I am emboldned to lay this mean Attempt of mine before your Lordship; trusting that it may at some time or other undergo a Trial, and by your Lordships Favour receive a meet Incouragement, and procure your Lordships Pardon, &c. to

My Lord,

Your Lordships most Obedient,

Humble Servant,

Robert Anderson.

TO THE
Young PYROBOLISTES.

Rockets are the most Artificial piece of Fire-work yet used amongst the Pyrobolistes, and hath been more used of late Years than formerly, and that the Young Artists may not spend their Time and Money unnecessarily, I have given easie, plain, and ready Rules for making of Rockets to two Inches and half Diameter, which is sufficient for all private Occasion, viz. Of the Mould of a Rocket. Of the Rouler and Case. Of the Compositions. Of the Receipts of Rockets. Of the Driver. Of the Boring of the Rocket. Of the Stars and other Matter to be put in the Head of a Rocket. To Head a Rocket. Of the Sticking of a Rocket. And lastly, to Fire the Rocket. And some Observations about the manage-

To the Young Pyrobolistes.

ment of a Rocket in general ; all which I hope will prove easie and beneficial to the Ingenious, and those that are willing to Learn : and what you do, endeavour to do it well, and do not be Conceited ; which if so, I have my ends. And from these little beginnings greater Masters may be obtained, and you may become serviceable to your Country, in which be sure to be Careful, Honest and Faithful.

TO

TO THE
Other PYROBOLISTES.

ABout fifteen Tears since I considered of a method to increase or decrease the strength of the Metal of Guns, which is this that I intend to discourse of. And at the Close of a small Treatise to hit a Mark published in the Tear 1691. I proposed that Problem in Print; since that time there has been more than Ordinary occasion for it, by Reason of the new Casting of the Mortar-pieces. About two Tears since I put that Problem into a method, and made a Draught of the whole matter to increase or decrease the strength of the Metal of a Gun in any possible Proportion assigned. But when I saw the Mortar-pieces brought from Sea broke, it was thought to be a good time to shew it, which

To the other Pyroboliftes.

which was done, and the whole matter discoursed of at large, but it signified 00. But now I apply that Problem to the making of Rockets for the young Artist, as you see in its proper place. And it is manifest that the young Rocket-makers of this City are very Careful and Artificial in their Rockets of 8 d. 12 d. or 18 d. value, otherwise they may break and so lose their Labour and Discredit themselves. Seeing these Mathematical Rules are so applicable to the greatest nicety of the Rising of all sizes of Rockets; is it not more valuable to be applied to those Chargeable Instruments of War, viz. Guns of all sorts, with their Carriages, and all other their Furniture?

As to the Doctrine of shooting by the increase and decrease of Powder, this way of making of Rockets proves it to be absurd; for all Rocket makers to this time weaken the Composition of their Rockets, as their Rockets are in greatness, or having greater quantities of
Composi-

To the other Pyrobolistes.

Composition; and that by chance, and without any Mathematical Demonstration.

And also by Experience, in Table June 1. 1691. and in the first Column Experiment 4, against that in Column 2 you will find 4 Ounces of Powder, and in Column 3, 3377. Again, in Column 1, against Experiment 1 in Column 2, you find $\frac{1}{2}$ an Ounce of Powder, and against that in Column 3, you find 213; now because the Requisite of Powder are as 8 to 1, therefore I multiply 213 by 8, and it makes 1704, much short of 3377, which indeed should have been equal to the said 3377. that is the Ranges upon the plain of the Horizon are not as the Requisites of Powder which projected those Ranges; the like may be done in all the other Experiments. I have made hundreds of Experiments in several sorts of Mortar-pieces, and am ready to make as many more, all which will manifestly confute the Doctrine of shooting by the increase and decrease
of

To the other Pyrobolistes.

of Powder, and have often invited the first promater of that Doctrine to see his Invention confuted; and I do here invite all the Practitioners in that Science of shooting by the increase and decrease of Powder, to come and see their Doctrine confuted. I do hear assert it is impossible ever to bring that way of shooting to be so exact and ready for use, in all or any sorts of Guns, as the common or usual way is, by keeping the Requisites of Powder constant, and elevating the Piece. In the Complicating of Rockets, whose Diameters are at any great distance; we make use of Experiments of shooting made upon another Occasion; and those Experiments serves sufficiently well; but if we were to do them justly according to Art, there should be two even Chased Guns of the same Proportion as the Rockets are of, that is the Diameter of the exposed Rocket $2\frac{1}{2}$ Inch multiplied by 6 is 15 Inches, and those should be the Diameter and length of one of the Guns: 4 Inches the Diameter of the other Rocket, multiplied by 6 is 24 Inches, which 4 Inches for the

To the other Pyrobolistes.

the Diameter, and 24 Inches for the length should be the other Gun, or any two Guns in that Proportion. For the Requisite of Powder take the Cube of 4, which is 64, as also the Cube of $2\frac{1}{2}$, which is 15.625, divide the greater Cube Number by the lesser, and the Quotient is 4, sufficiently near; so the Requisites of Powder of these two Pieces are as 4 to 1, then take any reasonable Requisite of Powder for the 4 Inch Gun, then take the fourth part of that Requisite for the Requisite of Powder for the lesser Gun, discharge them both at one degree of Elevation, and note their Ranges. Their Bullets are to be of the same Metal, and of the same likeness, and both exactly fit. In a Mathematical sense these Ranges should be equal; but by Combination the greater quantity of Powder aggitates more upon the great Bullet, than the lesser Requisites doth aggitate upon the lesser Bullet, and that causes those differences, the like when two quantities of Powder aggitate upon one Bullet; it is Experience only that deter-

To the other Pyrobolistes.

determines the matter. Although strange things sometimes happens; yet this we will Assert, and endeavour to maintain that Mathematical Knowledge, join'd with faithful Experiments, will do greater matters than most Men commonly conceive.

Rob. Anderson.

Rocket

ge
we
in
th
er
ga

Rocket Moulds are
made by Mr. Cuggley just
without *Cripplegate*.

Taper Bits for Rockets,
are made by Mr. Goode
just within *Cripplegate*.

Rods for Rockets, are
made by Mr. Stateham in
Token-House-Yard, Lothbury.
All three right good
Workmen.

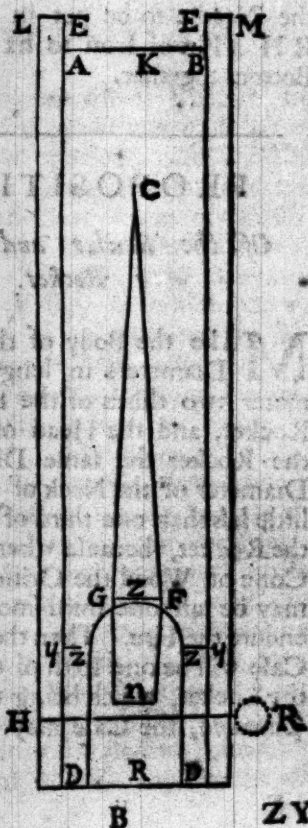
Wormen.
All three right good
Tobacco House-hold, Lardship.
made by Mr. Sturtevant in
Rods for Rockets, are
just within Gipsy's
are made by Mr. Good
Taper Bins for Rockets
without Gipsy's
made by Mr. Gipsy just
Rocket Monks are

PROPOSITION I.

Of a Rocket-Mould.

L Et EMR
LDDHLE

be a Rocket-Mould, A B the Diameter of it, *viz.* one Inch and half; Z K 4 Diameters; that is 6 Inches the height to be filled with Composition, B E half a Diameter an overplus, Z C the height of the boring 4 Inches and $\frac{1}{2}$, or $\frac{3}{4}$ of the height of the Mould, G F the Orifice one third of the Diameter of the Rocket half an Inch,



ZY one sixth of the Diameter of the Rocket a quarter of an Inch, the thickness of the Case, DYZGCFZYD the bottom of the Rocket-Mould with the Needle to be put in and taken out; RH a Pin of Iron to fix the Mould and Bottom together.

PROPOSITION II

Of the Rowler and Case of a Rocket.

MAKE the Body of the Rowler nine Diameters in length, and in Diameter two thirds of the Diameter of the Rocket, and the Head of the Rowler of the Rocket the same Diameter; let the Diameter of the Neck of the Rowler be a little less than one third of the Diameter of the Rocket, because when opened with a Cone of Wood the Orifice of the Rocket may be just one third smooth and hard to endure the Fire. Then the thickness of the Case will be one sixth of the Diameter of the Rocket, which being well Rowled and Choaked, the Case may be finished.

PROPOSITION III.

Of the Composition for Rockets.

THE Ingredients which Rockets are Composed of are Saltpetre, Sulphur, and Wood-Coal mealed, and passed through a fine Sieve. First, take the largest of Small-Coal made of Birch-Wood. Secondly, chuse the Yellowest Roch Sulphur. Thirdly, take Saltpetre put in a Brass Vessel, to which put so much fair Water as will dissolve it, put that Vessel upon the Fire, when it boils scum it clean; when the Water evaporates and consumes, stir it with a Spatula of Wood to meal it, what remains of the Saltpetre upon the Spatula, and sides of the Vessel, rub off with your Spatula of Wood; then meal it, and pass it through a fine Sieve. A second way to Clarifie Saltpetre; take a Crucible, set it in the Fire, put Saltpetre thereunto, increase the Fire till the Saltpetre be Reduced to a liquid quality like Water; when it boils take mealed Sulphur upon a Spatula of Iron, and put it into the boiling Saltpetre; so often repeated, the Flegmy quality of

B 2

the

the Saltpetre will be burnt away, and the flame will remain as white as the Body of the Sun. Then pour it into some very smooth Vessel, which being cooled, you may reduce it into meal. These ways I have done for my Recreation; but I usually take the cleanest Saltpetre to be found in Drugsters Shops, and it does as well.

PROPOSITION IV.

The Receipts for Rockets.

FOR an Inch, an Inch and half, and two Inch Rocket, and for a White Fire, take 2 Drams of Antimony, 1 Ounce of Sulphur 2 $\frac{1}{2}$ Ounces of Coal-dust, 6 Ounces of Saltpetre, and 8 Ounces of powder dust, [*Casimer du Grand Art d' Artillerie, Partie 1. Livre 3. pag. 145.*] Fill 4 Diameters and Bore 1 $\frac{1}{2}$. For an Inch and half, and two Inch, and two Inch and half Rocket, and a Yellow Fire, take 1 Ounce of Sulphur, 1 Ounce of Coal-dust, 4 Ounces of Saltpetre; or take 1 Ounce of Sulphur, 1 $\frac{1}{2}$ Ounce of Coal-dust, and 4 Ounces of Saltpetre. [*Casimer du Grand Art d' Artillerie, Partie 1. Livre 3. pag. 99.*] Fill 4 Diameters, and bore 3, or a little more

more. And *Daniel Elrich Der grossen Kunst Artillerie Zweiter, Theil* pag. 54. 22. 19. Advises to take 1 Ounce of Sulphur, one Ounce of Coal dust, 4 Ounces of Saltpetre. Again, take 1 Ounce of Sulphur, 2 Ounces of Coal, and 6 Ounces of Saltpetre; also take 1 Ounce of Sulphur 2 $\frac{1}{2}$ of Coal, and 6 of Saltpetre. *Johann. Sigmund. Buchner in Theoria & praxis Artilleria Andere Theil*, pag. 28. Weigh the Ingredients single, put them into a wooden Bowl, mix them very well together, and pass them through the Sieve, then your Composition is fit for use. In filling Rockets of one or two Inches Diameter; let them be filled at 6, 8, or 10 times Charging, and to every Charge 10, 12, or 14 blows with a Mallet, and betwixt every three blows turn the Driver a little in your Hand, so the Composition about the Needle will be preserved.

Some of our Rocket-Makers cry up the Compositions of *Woolverman* and *Nelson*, as though there was no Composition to be found like theirs, and they are thus: that falsely called *Woolverman's* is 1 of Sulphur, 1 of Coal, and 4 of Saltpetre: and that of *Nelson*, 1 of Sulphur, 1 $\frac{1}{2}$ of Coal, and 4 of Saltpetre, as they stand in the Remains of

Mr. *Francis Drake*, sometime Gunner of the *Tower*. These Compositions are Old and Common, as you see, they are Good, Strong, and dull Compositions, and easily mannaged. Those Compositions where Powder is judiciously mixed are more lively, and so more difficult to mannage.

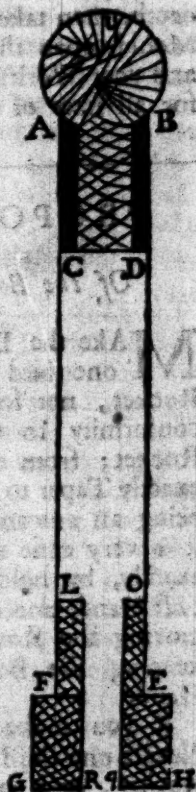
PRO-

PROPOSITION V.

Of the Driver of a Rocket.

L Et yAFGHEBy
be the Driver of
the Rocket, A FEB
a piece of a Gun Barrel,
FGHEOL a piece of
Box or hard Wood,
RLOq a hole for the
Needle to pass through,
ACDBy a piece of
Box to drive upon; this
we call a hollow Driver,
it dispatches business
quickly, and does
right well. Or you
may fasten a piece of
Brass in the end of your
Iron Driver with a hole
in it to receive the
Needle.

If any will use a solid
Driver, let them have
the bottom of the
Mould as DyZZyD
with a hole passing
through the bottom,
as Z R, for a strait
Piercer to pass through



which bottom will be a Guide to the Piercer to be just in the middle of the Rocket, make a mark in your Piercer to be a guide to bore always an equal depth, then take your Rocket out of the Mould, open the hole with a Taper bit, and your Work is done, thus you may do for all sizes of Rockets.

PROPOSITION VI.

Of the Boring of a Rocket.

Make the Diameter of your Borer one third of the Diameter of your Rocket, not for any necessity, but for conformity to the other parts of the Rocket; from that Diameter let it be exactly Taper to a point. Further, there being an entrance made by the Needle, it is very easie to bore the Rocket very exactly, by holding the Rocket in the Left Hand, and the Borer in the Right, moving the Rocket in the Left Hand, keeping the Borer fast in the Right Hand.

If you make the Diameter of the Needle one third of the Diameter of the Rocket, and so Taper, you need no Borer;

Borer; here you shall find the Rocket will rise swifter than when bored, the Composition lying looser about the Needle than if it were bored, takes fire easier, and this is most necessary in large Rockets, viz. of 3, 4, or 6 Inches Diameter; for such will hang too long time upon the Nails before they rise. Those Rockets whose Compositions are Composed of mealed Powder, Saltpetre, Coal and Sulphur, fill four Diameters, bore two and half. Those Composed of Saltpetre, Coal, and Sulphur fill four Diameters, bore three or a little more.

This will hold in Rockets of 1 Inch, $1\frac{1}{2}$ and 2 Inches, but in larger Rockets there must be less solidity to the hollow Cone of Fire. I used for many years to drive my Rockets solid, and to bore them after, but that way did no better than these I now use and deliver; but this is most certain that any one may drive and bore 3 Rockets with those hollow Drivers which I now use, whilst one many finish the driving and boring of one Rocket with a solid Driver; when the Rocket is near filled, use a shorter Driver with a smaller hole.

PROPOSITION VII.

Of Stars for Rockets.

- | | | | | |
|----|----|----|----|------------|
| 1, | 1, | 2, | 2. | Sulphur. |
| 2, | 3, | 3, | 2. | Antimony. |
| 4, | 6, | 8, | 6. | Saltpetre. |

Meal these Ingredients fine, pass them through a Sieve, mix them with Water in which some Glue, or Gum Araback, or Gum Dragon hath been dissolved, make them of the bigness of a Hazle Nut, or small Wallnut ; roul them in meal Powder, when dryed they are fit for use.

Rockets are headed with small Serpents, their Orifices washed with meal-ed Powder and Brandy Wine, to take Fire.

Of Rain and Hail.

TAKE any of those Receipts for Stars, viz. 1 Sulphur, 2 Antimony, and 4 Saltpetre; if you moisten that Composition with Oil of Petre only made well into Paste, formed into little Globes, rowled into mealed Powder; such Stars will have Red Colour: the same Composition moistned with Linseed Oil will have a Red mixed with White: the same Composition mixed with Oil of Petre and Linseed Oil mixed together, will make an Amethyst Fire. All these will require a long time a drying, the best time is to make them in the Summer.

The same Composition mixed with Gum Araback Water, and Colophone, gives a Red Yellowish Fire. The former Composition moistned with Brandy and Oil of Petre, or Linseed Oil, mixed together, requires less drying. Powder of Glass, Powder made of Sawdust mixed with the former Composition gives different Fire; Coal dust instead of Antimony, all which you may govern by your own Reason. Take the Old Proverb, *So many Men, so many Minds.*

(8.) To

PROPOSITION VIII.

To Head a Rocket.

TURN a piece of Wood just so big as your Rocket is, with a Cone at one end thereof, paste a piece of strong Paper about the Wood, then paste another piece of Paper about the Cone, and paste both Papers together; then put your Stars into this Paper Vessel, with some Rocket Composition to break the Vessel, then put a little Paste a little within the sides of this Paper Vessel, then draw it upon your Rocket, and paste it to the Rocket, so your Work is done.

PROPOSITION IX.

Of the Sticking of Rockets.

THE Stick of a Rocket ought to be seven times the length of the Rocket or more, viz. a Rocket of an Inch and half, six Diameters thereof, the length of the Rocket, is nine Inches, seven times

times nine is fixty three Inches, that is five Foot three Inches. The breadth of the Stick at the Head, three quarters of an Inch or less, the thicknes half an Inch or less, the small end of the Stick three eighths of an Inch and square, and to be made of light Deal; such a Stick will do very well, and may be counted Custom without Demonstration. In the Winter 1695. there were two sets of Fire-works, in the first of which the Wind was Northward, and the Rockets in their rising worked into the Wind. In the second the Wind was Westward, and had the same effect as the first; the Reason was because the Stick was too heavy at the upper end, and too light at the lower; and so the Center of Gravity of the Rocket and Stick was too near the Rocket: when indeed the Center of Gravity should be in the middle, betwixt the lower end of the Stick and upper end of the Rocket; and to do which the bigger end of the Stick ought to be downward; by this means a lighter Stick would serve, and if the Wind did drive the Rocket, the Rocket would move less, and yet perpendicular to the Horizon. Nature it self has taught us the same; for all Birds, especially Birds of a swift flight, spread their Tails for their Guide. Sticks of Rockets ought to be one
to

to another as the length and Diameters of the respective Rockets; that is, as the Diametre $1\frac{1}{2}$ Inch is to the thickness of its Stick, so is 4 Inches the Diameter of a 4 Inch Rocket to the thickness of its respective Stick. As the length of one Rocket is to its Stick; so is the length of any other Rocket to its Stick: and as the weight of one Rocket is to the weight of its Stick; so is the weight of any other Rocket to the weight of its respective Stick.

PROPOSITION X.

To fire the Rocket.

PLace the Rocket perpendicular to the Horizon by four Nails, make a port-fire, about half an Inch in Diameter, with single Paper, viz. 1 Sulphur, 2 Sawdust sifted fine, or rather Logwood beaten and sifted fine, 4 of mealed Powder, and 8 of Saltpetre; or make the port-fire with Rocket Composition: fire the port-fire, move it gently towards the Orifice of the Rocket till it takes fire.

Obfer.

Observations concerning Rockets.

(1.) IF a Rocket be driven not hard enough it either consumes or breaks; if just hard enough it rises well; if too hard it turns a loft, and breaks not at the just turn.

(2.) If a Rocket be bored not deep enough it will not rise well; if just deep enough it rises well; if too deep it often breaks.

(3.) If a Rocket be bored with too great a Borer it will not rise well; if with a fit Borer it rises well; if with too small a Borer it breaks, or rises not well.

(4.) If the Composition be too moist it will not rise well; if too dry it rises too fast or breaks.

(5.) If a Rocket be made, and kept in too dry or too moist a place, it will have the same effect as at the (4.)

(6.) The

(6.) The Velocity of a Rocket is caused by the boring, or in the hollow Cone; the time of its flight is in the solid part above the boring, which solid part ought to be less in a great Rocket than in a little one. From these Observations a Youth may take any Composition (in Reason) and make a good Rocket.

PROPOSITION XL

*The weight of the Mallets for
Rockets.*

THE weight of the Mallets which Rockets are driven with, ought to be as the Cube of the Respective Diameters of their bores, viz. If the weight of the Mallet for an Inch Rocket be twelve Ounces, the weight of the Mallet for an Inch and half Rocket ought to be two Pounds and half, and for a two Inch Rocket six Pounds, &c.

PRO-

PROPOSITION. XII.

How Rockets are estimated.

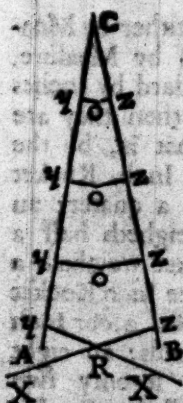
Rockets are estimated either by Measure or by Weight; if by Measure, then by the Common Standard by Inches or by Feet; if by Weight, then they are estimated by Cast Iron, that is, by the Gunners Rule, viz. An Inch Rocket weigheth two Ounces and a quarter; an Inch and half Rocket weigheth half a Pound: a two Inch Rocket weigheth a little above a Pound: a three Inch Rocket weigheth almost four Pounds: a four Inch Rocket weigheth nine Pounds: an eight Inch Rocket weigheth seventy two Pounds, which may be called a Rocket Royal.

C

PRO:

PROPOSITION XIII.

Of the cause of the Rockets rising.



LET ACB be the hollow Cone for the the Fire, $AyCZB$ the Superficies of that Cone, all the Lines OZ at right Angles with BC , and all the Lines Oy at Right Angle with AC ; now all the Angles ZOy being towards R , whether the Angles ZOy are Obtuse or Acute, but the more acuter the better. The Rays of fire ZO and yO issuing from the sides of the Cone BC and AC , and continually agitating with greater force one upon another at O , forcing the whole Cone BCA upward from the point R ; (and the wider the bore is (in Reason) the Rocket will rise with the greater velocity; if the Composition and deepness of boring be futable.) By the Rays ZX ,
and

and y Z of fire, crossing each other at the Center of the Cone R, and the point R, as it were, remains fixt; and here the similitude of Guns and Rockets appears plainly, a Gun remains fixt upon the Center of Motion of the Trunnions, and projects its burden forth; but a Rocket flies from its burden, leaving it at R, as it were fixt.

C 2

PART

PART II.

TO OUR PYROBOLISTES.

A duplicate Proposition.

HAVING one Rocket well proved in all its Parts, viz. a three Inch Rocket. Then,

To decrease the Velocity of the Composition of the aforesaid Rocket, to make it fit for a 4 Inch $4\frac{1}{2}$ and 5 Inch Rocket.

And to increase the Velocity of the aforesaid Composition, to adapt it to a 2 Inch $1\frac{1}{2}$ and 1 Inch Rocket, keeping the same kind of Boring.

Secondly, From the exposed Rocket of 3 Inches, to increase the Diameter of the Orifice of the Rockets of 4 : $4\frac{1}{2}$ and 5

C 3

Inches

Inches Diameter ; and to decrease the Diameter of the Orifice of the Rockets of 2 : $1\frac{1}{2}$ and 1 Inch Diameter , to adapt them to the exposed Rocket, keeping the Composition of the same Velocity.

*From Experimental and Mathematical
Demonstration.*

The Resolution of this Problem will manifestly shew, the invalidity of the Doctrine of Shooting by the increase and decrease of Powder ; and that weak and narrow Scantling it pinfolds in, *too mean for this lofty Engine.* It also tells the Gun-Founder how to give his Guns their due Fortification ; otherwise they may become useless Instruments of War. It teacheth our *Pyrobolistes* to direct their Work so that it may rise well, and not break nor fall. It teacheth Artificers to increase and decrease the force or strength of their Materials in any possible Proportion assigned.

This Proposition was publicly proposed three Months before the publication of this Book, but no Resolution given by any.

PRO:

PROPOSITION XIV.

The Complication of Rockets in Relation to their Borers.

FROM a 2 Inch and half Rocket, we Complicate other Rockets, viz. a four Inch Rocket thus, we take the Cube of 4, which is 64, also we take the Cube of $2\frac{1}{2}$, which is 15.625, with which we divide 64, the Quotient is 4; and so many times the lesser Rocket is contained in the greater, that is as 4 is to 1. Then I look into the Tables of Ranges for the year 1691. *June* 1, and in the second Column I find the requisite of Powder 1 and 4, and against the 4 in the third Column I find the Range 3377; and in the third Column against 1 I find the Range 652, which I multiply by 4, the Ratio of the Rockets, and it is 2608: Now if this last Number had been equal to 3377, the Range with the Quadruple of Powder, it would have confirmed the shooting by the increase and decrease of

C 4 Powder;

Powder ; but as it is short, it is a visible Demonstration of the error of that Doctrine : and if the Doctrine of shooting by the increase and decrease of Powder were true, there would be no need for our Pyrobolistes to give different Velocities of Compositions to different sizes of Rockets, but one Composition would have served all sizes ; which every Youth knows the Contrary.



In the Parabola AHZ let AG be 2608, and AH 3377 ; then GZ and HZ are the Velocities of the equal and unequal Ranges. *Toricellius 22. Prop. de motu projec. lib secund.*

Then as GZ the Velocity of the equal Range ; is to one third of the Diameter of the four Inch Rocket 1.333 ; so is HZ the Velocity of the unequal Range,

Range, to a larger Diameter of the 4 Inch Rocket, to keep the same Composition.

Or as the equal Range 2608, is to the unequal Range 3377; so is the square of the Diameter of the Orifice of the 4 Inch Rocket, to the square of the Diameter of the Orifice of the Rocket enlarged, keeping the same Composition.

Or as the equal Range 2608, is to the unequal Range 3377; so is the Area of the Orifice of the Rocket of 4 Diameter, when taking $\frac{1}{3}$ of the Diameter; to the Area of the Orifice of the same Rocket when enlarged, to bare the Composition that would serve a Rocket of two Inches and a half, taking $\frac{1}{3}$ of the Diameter of the Rocket for the Diameter of its Orifice.

Example.

2608	The equal Range	3.4'6308
3377	The unequal Range	3.528531
The Square of 1.333, &c. the Diam. of the equal Orifice}		.249660
Take the half		.361883
The Diam. of the new Orifice}		.189941
1.516 one Inch and half		

Take

Take another Example.

August 24. 1691. I look in Column 2, and find the Requisites of Powder half an Ounce, and 3 Ounces; and against those Requisites in Column 3 I find 1482 the unequal Range, and 236 the equal Range; which I multiply by 4, and it makes 944.

944 The equal Range	2.974972
1482 The unequal Range	3.170848
The Square of 1.333, &c. the equal Orifice	} .249660
	.445536
The Diameter of the new Ori- fice 1.67	} .222768

Here may be seen the concurrence of Experiments made upon another account, not then thinking to apply it to the Complication of Rockets. I made 2 Rockets of 4 Inches Diameter, and a Taper bit according to this method, and bored three Diameters, and left 2 Inches Solid, and they rose well.

An example of a Rocket of 6 Inches Diameter, keeping the same Composition. Take the Cube of 6, which is 216,
divide

divide that Cube by the Cube of 4, which is 64, the Quotient is 3, that is the Composition in the Rocket of 4 Inches, is to the Composition in the Rocket of 6 Inches, is as 1 to 3; then I look in the Table of *Aug. 24.* and find in the second Column the Requisites of Powder half an Ounce, and an Ounce and a half; and against these Requisites in Column three 800, the unequal Range, and 236 the equal Range, which I multiply by 3, and it makes 708: then as 4 is to 6, so is twelve half quarters of an Inch, the Diameter of the new Orifice of the four Inch Rocket, to eighteen half quarters of Inches; that is 2 Inches and 1 quarter: or as 4 is to 6, so is $1\frac{1}{2}$, that is 3 halves, to $4\frac{1}{2}$ half Inches, that is $2\frac{1}{4}$. Then I had no such Ranges, that their Requisites of Powder were in Proportion as the Cube of 6 is to the Cube of $2\frac{1}{4}$; therefore was I forced to help my self by Proportion, which is the same in Substance.

708 The equal Range	2.850033
800 The unequal Range	2.903089
The Square of $2\frac{1}{4}$, or 18 half quarters	2.510544
The half of this Logarithm	2.563600
Half quarters of Inches 19.13 that is $2\frac{3}{4}$ is	1.281800

A second Example, April 21. 1692.

I look in Column 2, and find the Requisites of Powder 12 Drums, and 36 Drums; and against these Requisites in the third Column I find 1176 the unequal Range, and 303 the equal Range, which I multiply by 3, and it makes 909.

909 The equal Range	2.958564
1176 The unequal Range	3.070407
The Square of 18 half quarters	2.510544
	2.622387
20.47, that is 2 Inches and a half, and $1\frac{4}{10}$	1.311193

Here may be seen one Example makes the Diameter a little more than two Inches and a half, and in the other a little less, therefore we make the Taper Bores just two Inches and a half for a 6 Inch Rocket. To work from a two Inch and a half Rocket to an Inch, put the unequal Range in the first place, and the Work is done. The Composition these 4 and 6 Inch Rockets were made of, were 1 Sulphur, $1\frac{1}{2}$ Coal, and 4 Saltpetre; but I believe 1 Sulphur, 1 Coal, and 4 Saltpetre would do better, there being no great

great danger of the Rocket breaking, by Reason of the large Diameter of the Bore, and Tapering to a point; and by the same Reason, a lesser solid Head is required, that is about 2 Inches in a 4 Inch, and $1\frac{1}{4}$ in a 6 or 8 Inch Rocket, will suffice.

PROPOSITION XV.

The Complication of Rockets in Relation to their Composition, with some Cautions and Limitations.

TO decrease the Velocity of the Composition of 1, $1\frac{1}{2}$, and 4, which served to a $2\frac{1}{2}$ Inch Rocket, to make it fit for a 4 Inch Rocket: remember the Ratio of the Rockets are as 1 to 4. Look in the Table of Ranges, and find the Requisites of Powder in the second Column, as 1 to 4, and against them in the third Column the Ranges, viz. 3377 and 652, then multiply the equal Range by 4, and it is 2608, (in fig. 1.) In the Parabola Z A H, let A H be equal to 3377, and A G equal to 2608; then H Z, and G Z will be the

the Velocity of the Powder, which projected those Ranges, and we increase or decrease the Velocity of the Salpetre by the Ratio of GZ to HZ: then let AC in fig. 2, be equal to HZ in fig. 1, and AB in fig. 2, be equal to GZ in fig. 1; then draw the Ordinate CH and BG in fig. 2, and by these two Lines, *viz.* CH and BG we increase or decrease the Velocity of the Coal. Further; let DF in fig. 3, be equal to CH in fig. 2; and DE in fig. 3. be equal to BG in fig. 2: draw the Ordinates FK and EI, and by these 2 Lines we increase or decrease the Velocity of the Sulphur.

Then if we take the Logarithm of

(0)	(1)	(2)	(4)	(8)
3377	3.518531	1.759265	0.879632	0.439816

And is

2608	3.416308	1.708154	0.854077	0.427038
------	----------	----------	----------	----------

that is, the Ranges under (0), their Logarithm under (1) the half of the Log. under (2), the numbers answering those Logarithms are the Lines HZ and GZ in fig. 1. The Logarithm under (4) is the fourth part of the Logarithm under (1): The Numbers answering these Logarithms, are the Lines CH, and BG in fig. 2.

fig. 2. Further, the Logarithm under (8) is the eighth part of the Logarithm under (1); the Numbers answering those Logarithms, are the Ordinates F K and E I in the Parabola F D K.

Or you may take the difference
of the Logarithms under (1) } 102223
viz.

Half	51111
Quarter	25555
Eighth	13777

By Adding or Subtracting these Log. to or from the Logarithm of the Saltpetre, Coal, and Sulphur, you have your desire, *viz.* their Velocities either increased or decreased: or thus, take the difference of the Logarithm of the two Ranges 102223, and Subtract it from the Logarithm of the Square of the Number of Drams, Ounces, or Pounds of Saltpetre, or from the Logarithm of the fourth power of the Numbers of Drams, Ounces, or Pounds of Coal. And Lastly, that difference being Subtracted from the Logarithms of the eighth power of the Number of the Drams, Ounces, or Pounds of Sulphur, there will remain three Logarithms, the first being divided by 2, the
second

second by 4, and the third by 8; there will remain three Logarithms, the Numbers answering to which, will be the Number of Drums, and Tenths of the Saltpetre, Coal, and Sulphur desired.

To Weaken the Velocity of the Composition of 1, $1\frac{1}{2}$, and 4.

3377 The unequal Range 3.518531

2008 The equal Range 3.416308

The Square of 64 Drums of }
Saltpetre } 3.612360

Take the half 3.510137

Drums 56.9 nine Tenths of }
Saltpetre } 1.755068

The fourth power of twenty }
four Drums of Coal } 5.520844

The difference of the Logarithm of unequal, and }
equal Ranges Subtract } .102223

Is the Logarithm of the fourth }
power, which being divided }
by fourth } 5.418621

22 Drums $\frac{11}{100}$ of Coal 1.354655

The

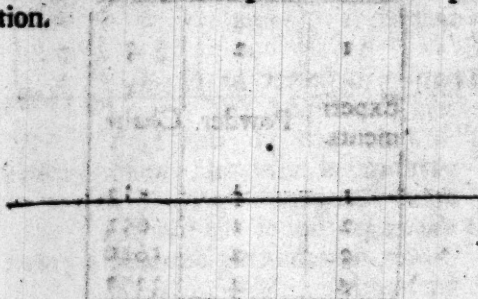
The eighth power of sixteen } 9 632960
 Drams of Sulphur

The difference of the Loga- } .101223
 rithm Subtract

Is the Logarithm of the eighth } 9.530737
 power which being divi-
 ded by 8

15 Drams $1\frac{1}{10}$ of Sulphur 1.191342

The Composition will be Sulphur $15\frac{1}{10}$,
 Coal $22\frac{1}{2}$, and Saltpetre 57; but if you
 quicken the Velocity, the equal Range
 will be in the first place of the Propor-
 tion.



D

PRO-

PROPOSITION XVI.

*Tables of Ranges made with
Mortar-pieces.*

June 1. 1691. On Wimbleton-Heath at
15 deg. of Elevation, with a four
Inch Mortar-piece, and a turned Iron
Ball.

1	2	3
Experi- ments.	Powder.	Chain.
1	$\frac{1}{2}$	213
2	1	652
3	2	1640
4	4	3377

August.

*August 24. 1691: At 15 deg. of Elevati-
on, with a $3\frac{1}{2}$ Inches Mortar-piece, and a
turn'd Iron Ball.*

1	2	3	4	5
The Chamber of this Mortar-piece a Frustum of a Cone.			The Chamber of this Mortar piece a Frustum of a Sphere.	
Powder Chain.			Powder Chain.	
1	$\frac{1}{2}$	136	$\frac{1}{2}$	144
2	1	496	1	304
3	$1\frac{1}{2}$	800	$1\frac{1}{2}$	1258
4	2	1482	2	2394

D 2

April

*April 21. 1692. At 15 deg. of Elevati-
on, with a 3 ½ Inch Mortar-piece, and
a turn'd Iron Ball.*

1	2	3
Experiment.	Powder.	Chain.
1	12	303
2	24	746
3	36	1176
4	48	1820
5	60	2698

Thus have I given plain and easie Rules to the Young Pyrobolistes for the making of small Rockets; and also for the making of great Rockets, to them of a greater Knowledge and Purse, even such as was reputed impossible; for a 4 Inch Rocket was given in by our ablest Pyrobolistes to be out of size, and therefore impossible to rise. Now, if that 4 Inch Rocket was thought so, what will they say to them of 6, 8, 10 or 12 Inches Diameter; for certainly this Rule takes in all sizes to 500 or 1000 weight, or higher.

Necessa-

Necessary Tables for Rockets.

Inches and half Inches.	Pounds of Rockets.	Ounces	Ounces of Compos. for Rockets.	Pounds of the Mall.	Ounces
1	2	3	4	5	6
1		02	0001		12
1½		08	0004	0002	08
2	001	02	0010	0006	02
2½	002	04	0018	0011	11
3	003	12	0032	0020	04
3½	006	00	0051	0032	04
4	009	00	0076	0048	00
4½	012	13	0108	0068	08
5	017	09	0148	0093	12
5½	023	06	0197	0126	12
6	030	06	0256	0162	00
6½	038	10	0326	0206	06
7	048	04	0407	0251	00
7½	059	05	0500	0316	06
8	072	00	0607	0384	00
8½	086	06	0728	0460	09
9	102	08	0864	0546	12
9½	120	09	1016	0643	00
10	140	10	1285	0748	04
10½	162	13	1372	0868	03
11	187	02	1578	0998	04
11½	213	14	1805	1140	10
12	423	00	2048	1296	00

The Use of these Necessary Tables.

IN the first Column you have the Inches and half Inches, to 12 Inches. In the second and third Columns you have the weight of Pounds and Ounces of the Rockets, when six Diameters in length. In the fourth Column you have the Ounces of Composition to fill those Rockets 4 Diameters. In the fifth and sixth Columns you have the weight of the Mallets to drive those Rockets in Pounds and Ounces.

An Example in the whole, for a three Inch Rocket. I find 3 in the first Column under Inches and half Inches; in the second and third Column, under Pounds and Ounces of Rockets, I find three Pounds and 12 Ounces the weight of the Rocket when finished, being 6 Diameters. In the fourth Column I find 32 Ounces of Composition to fill 4 Diameters. In the fifth and sixth Columns I find 20 Pounds 4 Ounces for the Mallet to drive that Rocket.

When Rockets are of a great weight, the Mallet will be too heavy to manage, therefore do thus. The Mallet of a three Inch Rocket, viz, 20 Pounds weight is of

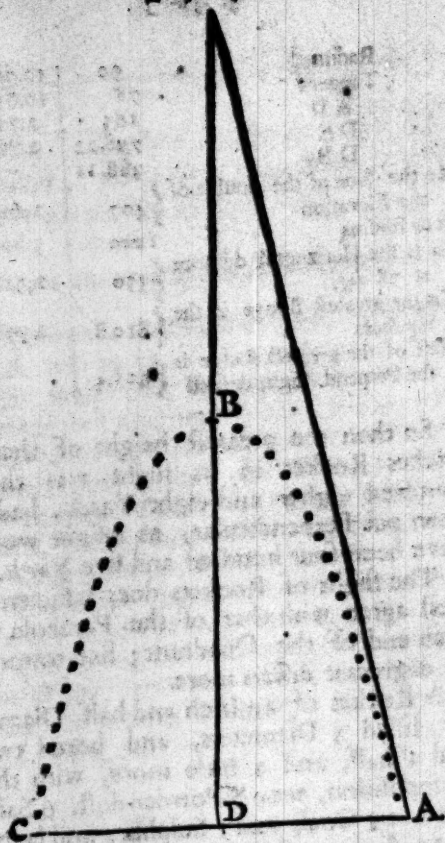
of a good size; and we will make an Example of a 3 Inch and $7\frac{1}{2}$ Rockets, and we will take it as useful that all Rockets to 3 Inches Diameter, may be filled with eight Charges, but further not, then against $7\frac{1}{2}$ in the first Column. In Column 4 I find 500 Ounces of Composition for that Rocket, which I divide by 8, and the Quotient will be 62.5. In the Parabola AHZ, let AH be the Number of Ounces 5062.5 in the Mallet for the $7\frac{1}{2}$ Rocket, and AG the Number of Ounces 324 in the Mallet for a 3 Inch Rocket; then the Ordinates HZ and GZ will be the Forces of those Mallets; then as HZ is to GZ, so is 62.5 to 15.811, that is 15 Ounces and $\frac{1.811}{1000}$ shall be your Charge of Composition. Further, divide 62.5 by 15.811, the Quotient will be 3.9529 the Number of Charges in the eight part of the Composition; then multiply 3.9529 by 8, there will be 31.6232 Charges in that Rocket. Lastly, give about eighteen blows to every Charge, with that Mallet for the 3 Inch Rocket, so your Work will be done, by two Men, in two hours.

324		2.510545
62.5 Squared		3.591760
5062.5 Sub.		6.102305
		3.704364
		2.397941
15.811 is Sub.		1.198970
62.5 is from		1.795880
3.9529 Rest		0.596910
8. Log.		0.903090
31.623 Sum of 2 Logarithm		1.500000
15.811 Add		1.198970
500. the Sum of Logarithm		2.698970

June 26. 1696. Then was fired a 4 and 6 Inch Rocket, Mr. Ayres Junior fired them both off a hand, Mr. Dandridge, Mr. Rodway, my self, and several other being present: the 6 Inch Rocket had 3 Inches solid Head, that is about the double of what it ought to have had, the Reason of that was to hold Fire; it moved off the Nails at about 78 deg. of Elevation, and the Horizontal Range was just 15 Chains, that is 330 Yards, by which we may find the Altitude of that Parabola it moved in, and the greatest Range, and Consequently the greatest Perpendicular Altitude it could have reached.

In

[41]



In the Parabola ABC, Let AC be equal to 330
Yards, AD equal to 165 the Angle DAE 78 degrees,
then in the right Angled Triangle EDA.

Radius

Radius	90	10.000000
Tangent	78	10.672525
A D	165	2.217484
D E	776.22	2.889989
D B	388.11	
As the Sine of the double of the Elevation	{ 407	2.609594
Is to Radius	1000	3.000000
So is the Horizontal distance at 78 deg.	{ 330	2.518514
To the greatest Range in the Parabola	{ 810.8	2.908920
Half of the greatest Range is the Perpend. height desired	{ 405.4	

So then the greatest height of that 6 Inches Rocket in its flight was three hundred eighty and eight Yards, had it been put Perpendicular, its height would have been four hundred and five Yards.

The flight of Rockets does sufficiently well agree with that of the Parabola at each end of the Quadrant; but towards 45 degrees it differs more.

A Rocket of an Inch and half Diameter, filled 5 Diameters, and bored two and a half, and a little more, with this Composition, *viz.* 8 Powder-duft, 6 Saltpetre, 2 $\frac{1}{2}$ Coal, and 1 Sulphur, and layed to 30 degrees of Elevation; Ranged the Rocket 880 Yards, that is half a Mile.

To make Rockets to Swim upon the Water, Dive into the Water, and keep above the Water.

An Example of an Inch Rocket.

MAke the Case 12 Diameters, which will be in this Example 12 Inches, fill it with two Compositions, viz. a Weaker and a Stronger; fill 2 Inches with the Weaker Composition, then 1 $\frac{1}{2}$ with the Strong, then 2 with the Weak, 1 $\frac{1}{2}$ with the Strong. Lastly, 2 Inches with the Weak, then there will remain 3 Inches for Corn Powder, for the Report.

The Weak Composition to Swim above Water; take 3 of meal Powder, 1 of Coal.

The Strong Composition to Dive under the Water, and leap above the Water; take 8 of mealed Powder, 1 of Saltpetre, and 1 of Coal.

To

To divide the Driver.

FROM the lower end of your Driver set off 3 Inches, then 2 Inches, then $1\frac{1}{2}$, then 2 Inches, then $1\frac{1}{2}$. Lastly, 2 Inches; make the Rockets of a just length, and so you may see the Divisions of the Driver appear above the Case as you fill.

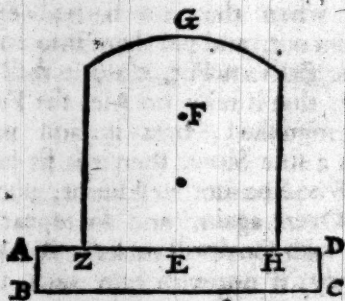
The Use.

Fire the Rocket in your Hand with your Port-fire, through it into a deep Water, (otherwise it will stick in the Mud) it will Swim a little while; but when the Strong Composition takes fire it will Dive, and when the Strong Composition is spent it will jump up, &c. The Weak Composition being the last, the Rocket for some time will Swim upon the Water, and then give a Report. This Rocket is all Solid.

To make a Rocket Charger.

LET the length of the Charger E G, be one Diameter and half, the breadth of the Charger H Z, one Diameter and one third, the length of the Neck

Neck of the Charger that slippeth upon the Handle BC, two Diameters; the breadth of that Ferril AB, one third of the Diameter of the Rocket: betwixt eight or nine of these Charges will fill a Rocket 4 Diameters.



You may cut the Charger ABCDH GZA in Paper, then it may be made in Copper, Close A to D, and B to C, Solder both ends together; bring H G Z into more than half a round, and AB and CD in a round, put it then upon a Handle, then it is fit for use.

To make good Coal for Rockets.

Take pieces of a light dry Deal Board about 12 Inches in length, and about the thickness of 2 Fingers or less; put them into an Oven, put fire to the Wood; when they are burned enough take them out, and put them into an Iron, Brass, or Earthen Pot, close it well with a Cover, that it takes no Air, the Fire being extinguished, beat it and pass it through a fine Sieve, then it is fit for use. If the Wood be not well burnt, put it into the Oven again, and so repeat your Work: such Coal will make a Rocket fly very lively, if not with too much Life.

Compositions for Reports.

	A	B	C	D
ii Saltpetre	9.	4.	3.	2.
Salt of Tartar	3.	3.	2.	1.
Sulphur	1.	2.	1.	1.

Take Sulphur 1, Tartar 3, and Saltpetre 9, grind these well together, and dry them. A few Grains of this Powder being fired, will give as great a Clap as a Musket when it is discharged. *Dr. French, pag. 171.* Take any of these Ingredients under

under A B C or D, mix them well together, put a little quantity of that mixture into a Fire-Pan, set it upon the Fire, and in a little time it will give a great Report.

A further use of the Tables.

WHat is done in the 14 and 15 Propositions, by taking the Cubes of the Diameter of the Bores of the Rockets, may be done by the Tables in 2 and 3, or Tab 4. Thus, look in the first Column for the Diameters of the Rockets, viz. 2, and 4, and against them, in Column 2 and 3, I find 2 Pounds and 4 Ounces, and 9 Pounds, divide the greater Number by the lesser, the Quotient will be 4, near enough, so the Ratio of these two Rockets are as 4 to 1, and this is by the weight of the Rockets.

In the other Example I find 4 and 6 in the first Column, and against them in Column 4, I find 76 and 256 Ounces of Composition for these two Rockets; then divide the greater by the lesser, the Quotient will be 3 and more, which is the same thing as if you made use of the Cubes of their Diameters; for indeed these Tables are made by the Cubes of the respective Diameters.

A Conclusion.

IF any one presumes to say they have Resolved the 14. Proposition before the Publication of this, they might have been so kind as to put it into Practice for the Defence of the Nation. If any say they can do it, I desire them so to do, *That I may see my desires accomplished, viz.* Great Guns and their Carriages truly fortified and neatly made, *which would be great satisfaction*; however this may shew to the next Age what has been offered to this.

July 25.
1696.



F I N I S.

